DOCUMENT RESUME

ED 230 366 SE 041 558

AUTHOR Hewson, Mariana G.
TITLE The Acquisition of Scientific Knowledge: Analysis and Representation of Student Conceptions Concerning Density.
PUB DATE [78]
NOTE 42p.; Light print may not reproduce well.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Concept Formation; *Epistemology; Foreign Countries; High Schools; Performance Factors; *Problem Solving; Science Education; *Science Instruction; *Scientific Concepts; *Secondary School Science
IDENTIFIERS *Density; Science Education Research; South Africa

ABSTRACT

Problems concerning conceptual change from existing knowledge (accumulated from everyday experiences or earlier teaching) to new scientific knowledge concerning natural phenomena are fundamentally the same for Western and non-Western students. However, difficulties experienced by non-Western students are magnified by factors such as their cultural experiences, beliefs, and language structure. In this study an attempt was made to analyze and represent the knowledge structures of a group of non-Western students from Qwa Qwa, South Africa (N=40) and to compare these structures with those involved in the orthodox scientific version of density. The study includes a description of the use made of these knowledge structures by selected students in solving the problem of why some objects float and others sink in water. Results indicate that few students' answers involved the Western scientific definition of density and that many answered in terms of alternative conceptions of mass, volume, density, and force. These and other results have implications for teaching Western science to students in a non-Western culture. They also have similar implications for science teaching within Western cultures where students acquire alternative conceptions which are a consequence of everyday experiences and which conflict with the orthodox scientific conceptions presented to them in school. (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED230366

THE ACQUISITION OF SCIENTIFIC KNOWLEDGE: ANALYSIS AND REPRESENTATION OF STUDENT CONCEPTIONS CONCERNING DENSITY.

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it
☐ Minor changes have been made to improve reproduction quality
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy

MARIANA G. HEWSON

NATIONAL INSTITUTE FOR PERSONNEL RESEARCH
P O BOX 32410, BRAAMFONTEIN, 2017,
SOUTH AFRICA.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Mariana G. Hewson
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

SE041558

Running head - Acquisition of Scientific Knowledge

THE ACQUISITION OF SCIENTIFIC KNOWLEDGE: ANALYSIS AND REPRESENTATION OF STUDENT CONCEPTIONS CONCERNING DENSITY*

ABSTRACT

The problems of learning science faced by Western and non-Western students are fundamentally the same. For both the problem concerns conceptual change from existing knowledge (i.e. knowledge accumulated from everyday experiences, or earlier teaching) to new scientific knowledge (i.e. formalised knowledge) concerning natural phenomena. The difficulties experienced by non-Western students are magnified by factors such as their cultural experiences and beliefs as well as their language structure. In this study an attempt has been made to analyse and represent the knowledge structures of a particular group of non-Western students in a particular subject area, namely density, and to compare the identified knowledge structures with those involved in the orthodox, scientific version of density. The study includes a description of the use made of these knowledge structures by selected students in solving the problem of why some objects float and others sink in water. An attempt is made to relate aspects of the students' intellectual environment to their task performance. The findings of this study have implications for both Western and non-Western science education.

* This research was assisted by a bursary from the Human Sciences Research Council, 1977-1978.

INTRODUCTION

The successful teaching of science to young people has proved to be difficult. Students in Black South African schools are no exception, finding science particularly difficult. Low pass rates in the final examinations in biology and physical science are evidence of this difficulty.

This study is concerned with how students acquire knowledge and focuses on the question of how they incorporate scientific knowledge into their own view of the world. The problems of learning science faced by Western and non-Western students are fundamentally the same. For both the problem concerns conceptual change from existing knowledge (i.e. knowledge accumulated from previous experiences) to orthodox scientific knowledge (i.e. formal knowledge concerning natural phenomena). The difficulties experienced by non-Western students may be increased by factors such as their cultural and religious beliefs, social and physical environments, and language problems (Seretlo, 1973). In this study an attempt has been made to analyse and represent the knowledge structures of a particular group of students in the subject area of density; describe the way in which these structures are applied by students in solving the problem of why objects float or sink in water; and compare the identified knowledge structures with those required by orthodox science.

In attempting to achieve these goals the study draws from selected theories concerning learning, the structure of knowledge and the purposes for which this knowledge is used by the individual.

Learning

Recent research on the teaching and learning of science has focused on three learning paradigms which have most promise for science education (Berger, 1979). These three paradigms are: the reception learning paradigm of Ausubel (1968); the hierarchical learning paradigm of Gagné (1964); and the developmental learning paradigm of Piaget (1963). Berger (1979) suggests that models or patterns of thinking can be viewed as paradigms which, if extensively researched, could lead to the development of a learning theory. While the three paradigms have been developed theoretically and research has been initiated, thus far none has been exploited sufficiently for it to be regarded as a basis for a complete theory of learning. The study reported here is mainly in the Ausubel reception learning tradition and uses aspects of the Piagetian approach.

Structure of Knowledge

The term cognitive structure may be represented as a hypothetical construct which refers to the organisation of concepts in knowledge (see Schwab, 1962). Shavelson (1974) describes knowledge as having both propositional and procedural structures. According to this view, the procedural structures concern the intellectual abilities

and strategies involved in thinking (for example, controlling and manipulating variables, formulating and testing hypotheses, applying knowledge, analysing and synthesising knowledge). The propositional structures consist of the fundamental components of knowledge, the concepts. These are connected to one another by means of propositional relationships which serve to give extended meaning to the concepts.

The propositional relationships in this study are described in terms of modified Piagetian operations. For example, propositions such as those involving identification, seriation and classification are simple relations, which involve two concepts related by a single proposition, for example, Mary is taller than Joan (seriation); a dog is a mammal (classification). On the other hand, the propositions involving compensations, correlations, and proportions are described as complex relations which involve 'relations of relations'. For example in the balance beam experiment, the heavier object must be less distance from the fulcrum on one side, while the lighter object must be a greater distance from the fulcrum on the other side for a balance to occur.

While knowledge consists of propositional and procedural structures, this study focuses more on the propositional than on the procedural structures. One reason for this is that philosophers such as Toulmin (1972) and Kuhn (1970) propose that the propositional structures (or

conceptual knowledge) actually modify what an individual perceives about a particular phenomenon, in much the same way that linguistic relativists like Whorf (1956) argue that the structure of language determines the way in which phenomena are perceived. In this study the term 'conception' will be used to incorporate both procedural and propositional structures.

Purpose of Knowledge

The study of man's way of acquiring knowledge has been the concern of many, including Toulmin (1972), who suggests that an individual's knowledge exists in a dynamic interaction with his or her intellectual environment. He uses the term 'conceptual ecology' to describe this interaction and to explain the existence of alternative conceptual frameworks, which he suggests are viable and provisionally valid to the individuals concerned. This philosophical position is reflected in psychological theories of knowing and learning. In this vein, Bruner (1973) writes that 'One cannot understand the organisation of behaviour without taking into account its directionality, its purpose, its intention - its teleological structure' (p.7). Furthermore, in the view of Bruner, Goodnow, and Austin (1956), the way in which individuals make sense of the world around them tends to reflect the intellectual tradition of their culture while the events that constitute the tradition, in their turn, are 'filtered' through the categorical systems that have been learned by the

individual. This interactive system echoes Toulmin's (1972) view of the dynamic interaction between knowledge and intellectual environment mentioned earlier.

P.W. Hewson (1981) has reviewed evidence to support the idea that individuals attempt to make sense of their world in some way, usually employing causal explanations and generalisations to impose some order on the experiences of the experienced universe.

The criteria by which knowledge can be acquired have been discussed by Posner, Strike, Hewson, and Gertzog (in press) who suggest that incoming information must be intelligible (i.e. understandable), plausible (i.e. realistic or possible), and fruitful (i.e. useful for some purpose). This is so because if new information is to be acquired by individuals it must, according to Ausubel (1968) be integrated and reconciled with the existing knowledge. It must therefore form a coherent, internally stable set of explanatory structures that account for the individual's experience and resolve as many apparent anomalies as possible.

Alternative Conceptions

The above descriptions of the structure and purpose of knowledge can be applied to the knowledge systems of groups and of individuals. Anthropologists such as Levi-Strauss (1966) and Horton (1967) have

described the conceptual systems of non-Western peoples as involving kinds of 'science' which are valid in that they serve to make sense of the real world and are the consequence of individuals' interactions with the real world. Thus, although the concepts and intellectual skills may differ from orthodox science, the commitment with which individuals interpret and explain their world is seen to be the same. (This is referred to as their epistemological commitment). Toulmin's (1972) term 'alternative frameworks' can thus be applied at a general level to describe the different thought systems of different groups of individuals, both culturally and historically. It can also be applied to particular individuals to account for the differences in knowledge which are clearly in evidence in every classroom. Certain aspects of these differences are discussed by Ausubel (1968) who refers to the existence of pre-conceptions and misconceptions that are 'amazingly tenacious and resistance to extinction'. Driver and Easley (1978) suggest that these pre- and misconceptions should be viewed as 'alternative frameworks', which develop as a consequence of everyday experiences. As with the thought systems of non-Westerners, they are often considered to be different from orthodox science, and may be viewed as wrong from the orthodox scientific point of view. They are, however, certainly useful, albeit in somewhat limited ways, to the individual concerned, i.e. they are intelligible, plausible, and fruitful to some extent. Their explanatory power may be viewed as less than that of Western,

orthodox science, and science instruction can be described as an attempt to provide students with more powerful conceptions than might otherwise be the case. In this study alternative frameworks are termed alternative conceptions. This is consistent with the view of knowledge described earlier.

There is increasing evidence of the existence of alternative conceptions in children's understanding of natural phenomena. Examples include studies concerning children's conceptions of heat (Erickson, 1980; Tiberghien, 1980); the earth as a cosmic body (Nussbaum and Novack, 1976); velocity (Trowbridge and McDermott, 1980); dynamics (Viennot, 1979); mechanics (Champagne, Klopfer, and Anderson, 1980), and a wide range of concepts in biology and general science (Gilbert and Osborne, 1980).

PROBLEM

This paper describes an attempt to examine the conceptions in a particular subject area of a group of students who come from a culture that is non-Western, whose living conditions are non-technological, whose home language is non-Western but who have been exposed to certain orthodox conceptions in science in schools which are modelled on the Western system of education. In particular the following problems are addressed.

1. What conceptions do a selected student group use in solving the problem of why some objects float and others sink when put in water?

2. What is the nature of these conceptions?
   (a) What concepts are involved?
   (b) What relationships are established between the concepts?
3. What kind of arguments or epistemological commitment do the students display in their responses?
4. Do the student conceptions differ from the scientific conceptions?

DESIGN

Selection of Students

Forty high school students (including 27 boys and 13 girls) with an average age of about 18 years (ranging from 14 to 22 years) were selected from the Form 3 class (i.e. 10 years of schooling) from four high schoolsin the Qwa Qwa area in South Africa. The students were selected on the basis of their scores on a scholastic aptitude test battery for Form 3 (van Staden, Ligthelm, du Toit, and Pottas, 1971). The initial requirement was that the students should have better than average scores in English (i.e. knowledge of English vocabulary and sentences), as the interviews were carried out in English. The home language of the subjects was Sesotho . The second requirement was that the selected students should represent a range of ability on the verbal, non-verbal, and mathematical reasoning ability tests. All students studied either mathematics or functional arithmetic and a combination of two of the following: physical science, biology, and a commercial subject.

The Floating and Sinking Task

The task replicated that described by Inhelder and Piaget (1958, p.20) and wasadministered in the form of a clinical interview (Piaget, 1929) in order to establish the nature and extent of each student's knowledge about the phenomena of floating and sinking. The task involved a bowl of water and an assortment of objects namely a nail, a needle, a curtain ring, a curtain hook, a small blue bead, a flat lid off a tin can, a large yellow flat plastic lid, a black plastic saucer, stones, corks, pieces of wood. The student was first asked to sort the objects into pilesof those which would sink and those which would float. Having done this, he or she was asked to give a generalized reason for the decisions and was then invited to check the categories by experimenting. In the course of this process, the student was asked non-directive questions to encourage him or her to enlarge on the statements made or the actions taken so as to reveal the conceptions.

Administration of the Task

The selected students were interviewed in their school buildings in a room set aside for the purpose. In order to overcome difficulties involved in cross-cultural testing, a facilitator (an adult Basotho man) was always present. His role was to help the subjects to feel at ease and to act as translator if any communication problems occurred. The interviews were recorded on both audio and videotape,

and were subsequently transcribed.

Analysis of the Transcripts

The information obtained from the clinical interviews was classified following the technique of Erickson (1979) with the intention of developing a compilation of the conceptions (a Conceptual Profile Inventory) for the student group. Selected individual students' statements were analysed for the type of conceptions and the relationships involved. Selected student manuscripts were represented schematically in order to show the conceptions, the explanations suggested and the general form of the argument used by the student (i.e. their epistemological commitment). Finally, the identified student conceptions were compared with orthodox scientific conceptions and were discussed in the context of the everyday life of the student group in general.

RESULTS

The data were analysed as follows:

Conceptual Profile Inventory

The response protocols of the students were analysed and the essential ideas expressed were summarized. There were interpreted as demonstrating the presence of particular conceptions. All conceptions were recorded including those subsequently rejected by the student in the course of the interview.

Table I shows the analysis of a section of a manuscript.

TABLE I ABOUT HERE

The conceptions concerning floating and sinking were categorized into groups and compiled into the Conceptual Profile Inventory (CPI), see Table II. Verbatim examples from the manuscripts are used to substantiate each conception category. In addition the number of students in each category is shown. The Conceptual Profile categories involved scientific conceptions of mass, volume, and density, and alternative conceptions of force, mass, volume, and density. The interjudge reliability ratings (i.e. the percentage agreement of the judges n=12, with the author) for these categorizations from two transcripts were 82% and 85%, which was considered satisfactory.

TABLES II & III ABOUT HERE

The distribution of conceptions amongst the students is given in Table III. This shows the range of conceptions used by each student. It is of interest that while a majority (33) of students made use of a scientific conception of mass (CPI: C.1) it is clear that during the interview about half (15) of them were also using an alternative conception of mass (CPI: C.2). Similarly, of the five students who used the scientific conception of density (CPI: E.1), four also used the alternative conception of density (CPI: E.2) where density is denseness of particles. It is clear therefore that many students

fluctuated between using scientific and alternative conceptions and many students had both types of conceptions. The alternative conceptions of force (CPI: B) appear to be spontaneous or naive preconceptions of an undifferentiated conception involving force, strength, energy, and power. The alternative conception of volume (CPI: D.2) is best described as a vague idea of size, quantity, or capacity. Interestingly, only one student was identified as having a scientific conception of volume.

Conception Analysis

The analysis of the student statements taken from the Conceptual Profile Inventory showed that the conceptions identified involve both simple and complex relations (Table IV). Only the scientific conception of density as mass per unit volume involved the complex relations of proportional correlations. It is of interest, however, that the alternative conception of density as denseness does involve correlations (complex relations). Thus complex relational thinking is not necessarily limited to scientific conceptions.

TABLE IV ABOUT HERE

Epistemological Analysis

Five transcripts, selected as being representative of the categories of the CPI were analysed in order to determine the epistemological commitments held, i.e. the general forms of argument used. The extent to which arguments were causal or precausal and the extent to which the conceptions were intelligible, plausible, or fruitful, is discussed. One of these analyses is shown in Figure 1.

These analyses were represented schematically in the form of flow charts. The figure shows the conceptions used by the student (represented in a box), the connections between the conceptions and the original question (shown as arrows), the summarised explanations, and a description of the general epistemological position of the student. Each conception is cross-referenced both to the Conceptual Profile Inventory and to the statements (given as numbers) from the original student transcript. In some cases, the student's conception was inferred by the assessor, and these were indicated with dotted lines.

FIGURE 1 ABOUT HERE

The analyses of the epistemological commitment of the selected student transcripts show that each student attempted to look for causal reasons to explain the floating and sinking of objects in water.

Student MAK 38 (see Figure 1) produced unrelated suggestions which generally concerned the morphology of the objects. The reasons given were idiosyncratic in nature, i.e. each object had a causal reason to account for floating and sinking based on concrete observations. This demonstrated the absence of a commitment to find an explanation which could be generalised to a variety of objects or events. This is a severe limitation for any student learning science. Relatively few students (25%) were in this category, and the remaining students demonstrated a clear commitment to find a generalisable reason which would explain and predict the behaviour of objects in water.

One student (MAN 73) indicated that he was aware that his suggested reasons involved contradictions, but stated that 'there must be a reason' which explained floating and sinking. Thus for this student, the reasons given were intelligible but he was aware that they were not really plausible or fruitful.

Student SEL 54 described the floating and sinking of objects in terms of density where density is mass per unit volume. His explanations involved generalisations and were intelligible, plausible, and fruitful. It is of interest that this student embarked on alternative explanations of density in terms of packing of particles, and volume, but apparently realised the clumsiness of this line of argument and resorted to the more parsimonious description of scientific density

as mass per unit volume.

Students MAM 135 and MAK 104 used explanations involving alternative conceptions of density and mass. These conceptions resulted in contradictory statements, and one of the students (MAM 135) clearly became insecure. He abandoned his argument linking mass and morphology, and resorted to the alternate conception of density as the packing of particles. His preference for this explanation suggests he found it intelligible and plausible, even if not particularly fruitful.

Comparison of Student Conceptions with Scientific Conceptions.

Conceptual networks wereused to compare student and scientific conceptions (see Stewart, 1980), and are represented in Figure 2.

FIGURE 2 ABOUT HERE

A prototype of a possible scientific conception of density which was obtained from a physics lecture is represented in Figure 2a. This diagram illustrates that the conception of density depends on an understanding of both mass and volume, involving a complex propositional relationship of proportional correlation. The conceptions of mass and volume depend on conceptions of particles, their arrangement, concentration, and particle mass. The propositional relationships between these concepts are complex as they involve direct or indirect

correlations. The conception of the material of the objects involves only a simple relationship of association or identification.

The comparison of selected student responses with the scientific prototype is seen in Figures 2b-f. The arrangement of concepts (squares) in each network is the same. The concepts are only written in when identified in the student transcript. Alternative conceptions are indicated with dotted lines.

The comparison of the identified student conceptions concerning density illustrated the following:

1. Important concepts were missing. The students represented in Figure 2b-f each showed a number of missing concepts. The scientific conception of volume was missing in most students. The conception of particular particle mass/weight was absent in all the students.

2. Alternative conceptions were present. Each of the students in Figure 2b-f made use of alternative conceptions, e.g. alternative conception of mass/weight (Figure 2b), alternative conception of volume (Figure 2e), and alternative conception of density (Figure 2f).

3. The relationships between the concepts involved simple and complex relations. Despite the fact that these students did not display scientific conceptions, the relationships between the concepts involved both simple and complex relations (e.g., proportional

and direct correlations). One exception to this was student MAK 38 (Figure 2b) who made no attempt to relate the concepts to each other.

DISCUSSION

It is necessary to look for possible reasons for the results obtained in this study. Some of these, which include the factors suggested by Seretlo (1973) mentioned earlier in this paper may be the following: (1) Effect of inadequate science teaching and facilities; (2) Effect of background and environment; (3) Effect of learning in a second language.

Effect of Inadequate Science Teaching and Facilities.

While it is clear that the schools visited for this study are amongst the best in the area, Black schools in South Africa are generally of poor standard. They have limited financial resources which means that facilities such as school laboratories and libraries are poorly equipped. Teachers are well motivated but are often inadequately trained in their subject areas, particularly in science. One contributing cause is that the teachers themselves are products of similar schools. The teacher qualifications are low, and there are very few teachers with degrees in the high schools. One of the consequences of this situation is that teachers use a 'catechism' style of teaching in which rote learning is prevalent. While the

concept of density is difficult to teach in most schools (see for example, Chiapetta, 1976), if teachers are unsure of the concept themselves, the task is made more difficult. It is possible that many teachers are using alternative conceptions and informal evidence to support this has been found in certain Black schools.

Effect of Background and Environment.

Many people living in the Qwa Qwa area fetch water from nearby rivers. Most people do not have bath tubs and children have little opportunity to play games involving the displacement of water as may occur in the bath tub. Water containers are generally irregular and uncalibrated so that precise measurement of volume in the home is relatively uncommon. The child growing up in this environment is likely to have different experiences with water and measurement of volume from the child in an urban, technological environemnt. It is conceivable, therefore, that the scientific conception of volume is less relevant or useful in a rural, non-technological environemnt such as Qwa Qwa, and is therefore likely to be either non-existent or undifferentiated.

Effect of learning in a second language.

The home language of the students was Sesotho. Basotho children begin learning English and Afrikaans in the primary grades, where the medium of instruction is Sesotho. On entering high school with 7 years of schooling the students learn all subjects in the medium of English. Thus, the Form III students used in this study were in

their third year of instruction in the medium of English. Although the students were selected for testing on the basis of their ability to understand English vocabulary and sentences, the fact that they were not operating in their home language could reflect in their task responses.

At this point it is of interest to consider the Sesotho words for weight, volume, and density, and the context in which they are used. In Sesotho the word for'weight' is 'boyima' and it is most often applied to solid objects rather than liquids. The word for 'volume' is best translated by 'bongata' which literally means amount or quantity of something. It may be applied to liquids such as milk or water or certain solid substances which are contained by something, such as flour in bags, and potatoes in sacks. It is also applied to numbers of people at a gathering or in a house. The concept of amount (i.e. 'bongata') appears to be applied to contained substances which can be counted, for example, 'the amount of water is three cups full'; 'the amount of potatoes is four bags'. Thus in each case the word 'bongata' is qualified by a referent i.e. the cups or bags which would be accepted as known, standard amounts. The concept of volume as the amount of space occupied by all matter has no exact Sesotho equivalent.

The English word 'density' is best translated by the Sesotho verb 'te teyana' meaning 'to be dense', 'to be thick' or 'to be crowded'.

This is similar to the everyday use of 'density' in English which applies to a number of objects per given area, as in 'a dense forest'. This everyday meaning of 'dense' appears to explain why so many subjects became involved in discussions about the denseness of particles, as described in CPI: E.2.

It would thus seem that the concepts which were used by subjects in solving the problem of floating or singking might be explained in terms of the linguistic structure of their home language. This could be interpreted as a weak form of the Whorfian (1956) hypothesis and of the view that the language of a culture provides the categories used or adapted by an individual (Bruner, Goodnow, and Austin, 1956). However, Toulmin's (1972) idea of conceptual ecology appears to provide an alternative interpretation. According to this view, the dynamic interaction between an individual and the intellectual environment in which he or she lives results in the acquisition of some concepts and not of others. The existence of particular conceptions indicates that they are useful in some way and that the individual is committed to them to some extent. The degree of differentiation, elaboration, and integration of the conceptions depends on how useful they are to the individual. The finding of this study that some conceptions may not exist at all and others may exist as alternatives to orthodox science can be explained in these terms.

SUMMARY

The results of the clinical analyses of Basotho high school students on the problem of floating and sinking show that relatively few students answered in terms of the Western scientific definition of density, and that many of them answered in terms of alternative conceptions of mass, volume, density, and force. These results indicate that the new conceptions of orthodox science do not necessarily replace the existing conceptions, but both may exist together, as an unresolved anomaly. The alternative conceptions did not differ from the scientific ones in terms of the kind of propositional relationships that were identified. The students attempted to give rational explanations of the phenomena of floating and sinking, and while the explanations were not necessarily scientific in an orthodox way, they were consistent and causal in character. The identified alternative conceptions probably reflect the students' everyday experiences as well as the structure of their home language, and also other factors such as beliefs and values which form part of their intellectual environment. These results suggest that the formal instruction received by these students had been unsuccessful with respect to the basic concepts of mass, volume, and density. Furthermore, the results suggest it might be the presence of alternative conceptions which prevents or blocks the learning of orthodox scientific conceptions. This point is taken up in a subsequent paper. (Hewson, M.G. and Hewson, P.W. in preparation).

These findings have implications for the teaching of Western science to students in a non-Western culture in terms of the instructional strategies employed by curriculum designers and teachers. They also have similar implications for science teaching within Western cultures where students acquire alternative conceptions which are a consequence of everyday experiences and which conflict with the orthodox scientific conceptions presented to them in school.

The role played by alternative conceptions in students' existing knowledge requires concerted attention from educators. The review by Driver and Easley (1978) indicates the growing interest in this subject, and in recent years the number of researchers involved in identifying alternative frameworks has grown considerably. The implications of this research for curricula and instructional strategies are many, but the first requirement is to explore individuals' conceptual frameworks in as great depth and as widely as possible.

REFERENCES

Ausubel, D. Educational psychology: a cognitive view. New York: Holt, Rinehard and Winston, 1968.

Berger, C.F. What are the implications of paradigm-based research for science education research? Journal of Research in Science Teaching, 1979, 16, no.6, 517-522.

Bruner, J.S. Patterns of growth. Inaugural lecture at the University of Oxford. Oxford: Clarendon Press, 1973.

Bruner, J.S., Goodnow, J.J., and Austin, G. A study of thinking. New York: Wiley, 1956.

Champagne, A.B., Klopfer, L.E., and Anderson, J.H. Factors influencing the learning of classical mechanics. American Journal of Physics, 1980 (a), 48, 1074-1079.

Chiapetta, E.L. A review of Piagetian studies relevant to science instruction at the secondary and college level. Science Education 1976, 60, 253-261.

Driver, R. and Easley, J.A. Pupils and paradigms: a review of literature related to concept development in adolescent science students. Studies in Science Education, 1978, 5, 61-84.

Erickson, G. Children's viewpoints of heat. Science Education, 1980, 64, 323-338.

Finley, F.N. An empirical determination of concepts contributing to successful performance of a science process: a study of mineral

classification. Paper presented at the annual meeting of the National Association of Research in Science Teaching. The Catskills, New York, 1981.

Gagné, R.M. The conditions of learning. New York: Holt, Rinehart, and Winston, 1964.

Gilbert, J.K., and Osborne, R.J. Identifying science students' concepts: the interview-about-instances approach. In W.F. Archenhold et al (Eds.) Cognitive development research in science and mathematics. Leeds: University of Leeds Printing Service, 1980.

Hewson, P.W. A conceptual change approach to learning science. European Journal of Science Education. 1981, 3, 383-396.

Hewson, M.G., and Hewson, P.W. The effect of instruction using students' prior knowledge and conceptual change strategies on science learning. Journal of Research in Science Teaching. In press.

Horton, R. African traditional thought and Western science. Africa, 1967, 37, 50-87.

Kuhn, T. The structure of scientific revolutions (2nd edition). Chicago: University of Chicago Press, 1970.

Levi-Strauss, C. The savage mind. Chicago: University of Chicago Press, 1966.

Nussbaum, J. and Novack, J.D. An assessment of children's concepts of the earth using structural interviews. Science Education, 1976, 60, 535-550.

Piaget, J. The child's conception of the world. London: Routledge and Kegan Paul, 1929.

Piaget, J. Psychology of intelligence. New Jersey: Littlefield, Adam (rep. by arrangement with Humanities Press), 1963.

Posner, G.J., Strike, K.A., Hewson, P.W., and Gertzog, W.F. Accommodation of a scientific conception: toward a theory of conceptual change. Science Education. In press.

Schwab, J.J. The concept of the structure of a discipline. Educational Record, 1962, 43, 197-205.

Seretlo, J.R. Some factors influencing the African's attitude to science and his performance therein. Inaugural lecture given at the University of Fort Hare, Alice: Fort Hare University Press, 1973.

Shavelson, R.J. Some notes on how to teach mathematics: a cognitive psychologist's point of view. Paper presented at the annual meeting of the American Educational Research Association, Boston, 1980.

Stewart, J. Content and cognitive structure -- critique of assessment and representation techniques used by science education researchers. Science Education, 1979, 63, no.3 , 395-405.

Tiberghien, A. Modes and conditions of learning -- an example: The learning of some aspects of the concept of heat. In W.F. Archenhold et al (Eds.) Cognitive development research in science and mathematics. Leeds: University of Leeds Printing Service, 1980.

Toulmin, S. Human understanding, Vol.1: The collective use and evolution of concepts. Princeton: Princeton University Press, 1972.

Trowbridge, D.E., and McDermott, L.C. Investigation of student understanding of the concept of velocity in one dimension. American Journal of Physics, 1980, 48, no.12, 1020-1028.

Van Staden, J.D., Ligthelm, G.J., du Toit, J.P., and Pottas, A.P.J., Guidance test for junior secondary Bantu pupils in Form 3. Pretoria: Human Sciences Research Council, 1971.

Viennot, L. Spontaneous reasoning in elementary dynamics. European Journal of Science Education, 1979, 1, no.2, 205-221.

Whorf, B.L. Language, thought, and reality. Boston: MIT Press, New York: John Wiley and Sons, Inc., 1956.

LIST OF FIGURES

Figure 1. Analysis of transcript MAK 38.

Figure 2. Representations of prototype of scientific conception of density (a), and five student explanations of density (b-f).

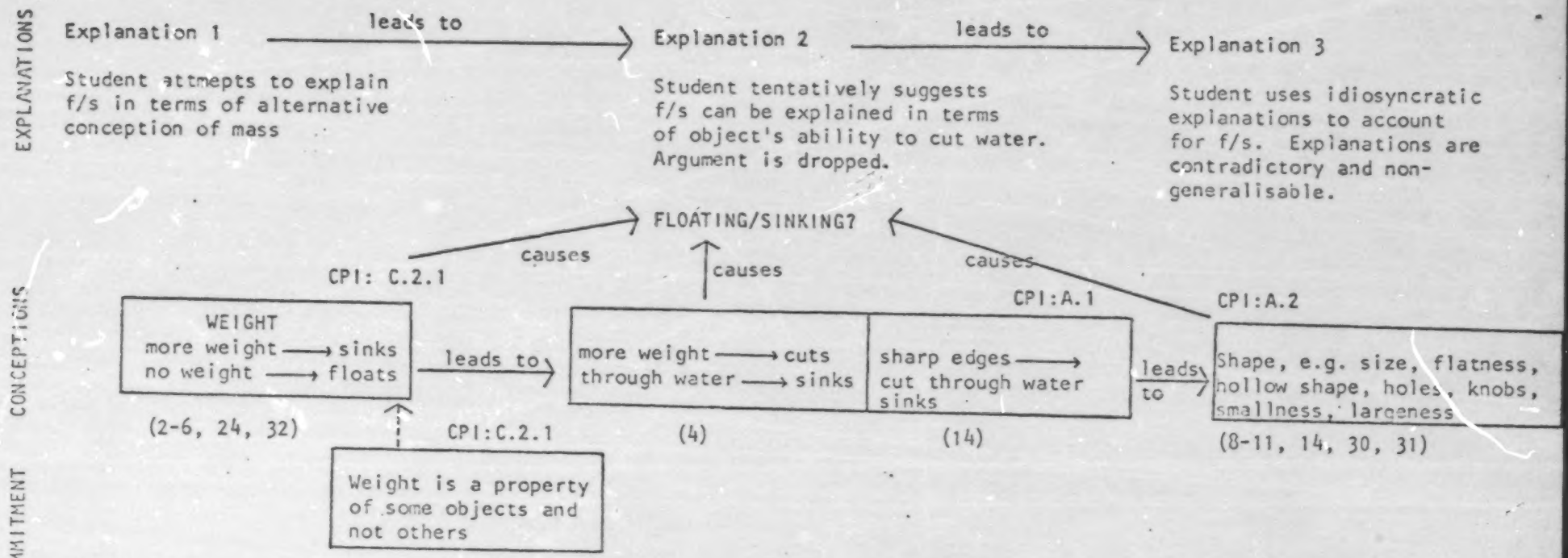
LIST OF TABLES

TABLE I. Analysis of Section of a Transcript for student MAK 124.

TABLE II. Conceptual Profile Inventory.

TABLE III. Distribution of Conceptual Profile Inventory Categories Amongst Student Group.

TABLE IV. Analysis of Relations Involved in Conceptual Profile Inventory Exemplars.



General

Student attempts to explain floating and sinking in terms of an alternative conception of mass/weight. The limitations of this argument seem to cause him to resort to idiosyncratic arguments concerning morphology which are based on the idea that every object has a particular reason for floating or sinking. The reasons suggested seem to be intelligible and even plausible to this student, but not fruitful since he gains no explanatory or predictive power, and are lacking generalisability.

Notes

The references CPI refer to the Conceptual Profile Inventory
The numbers refer to verbatim statements in the transcripts
The hatched arrows are connectors inferred by the author

Figure 1. Analysis of Transcript of Student MAK 38

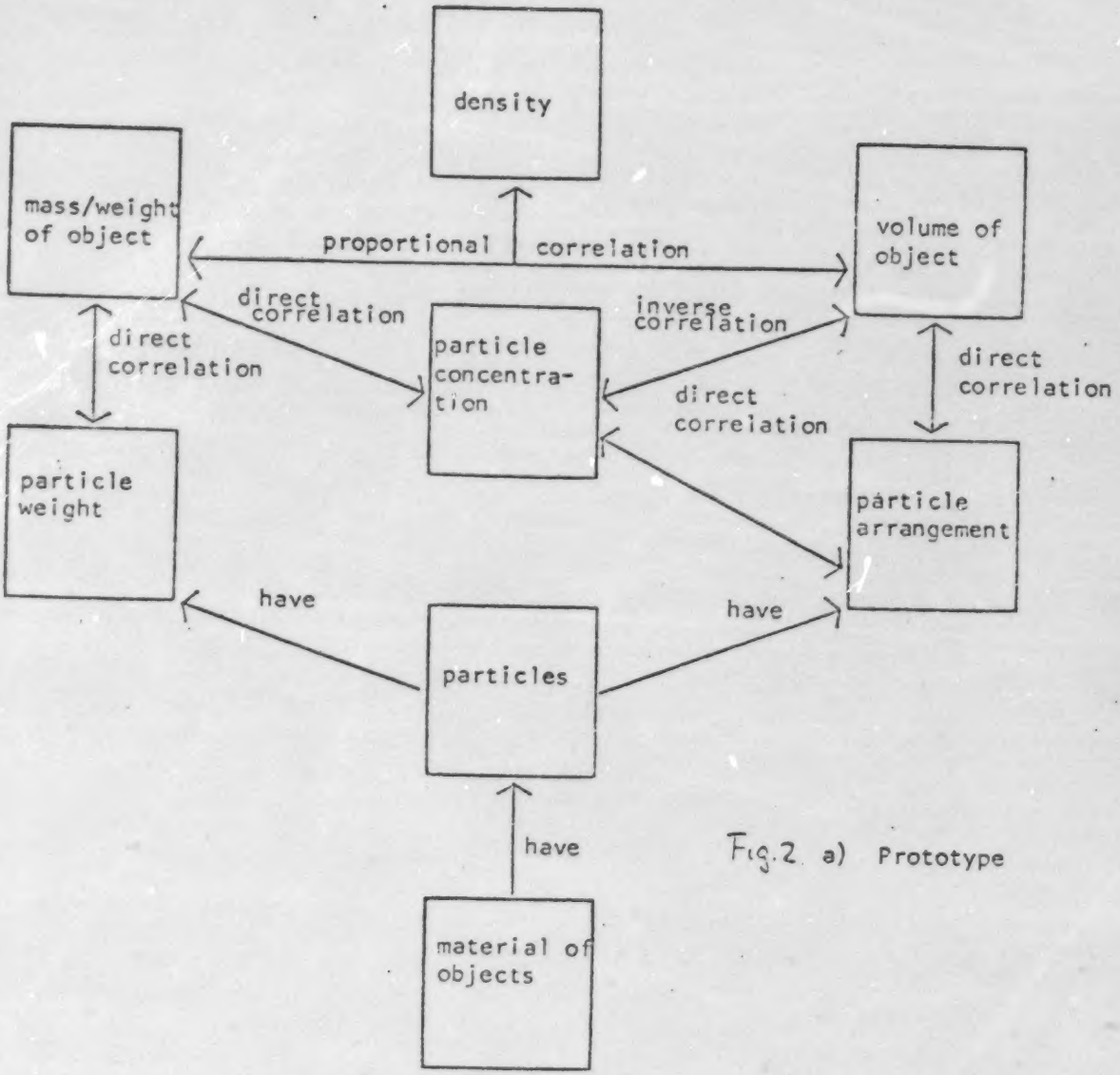


Fig.2 a) Prototype

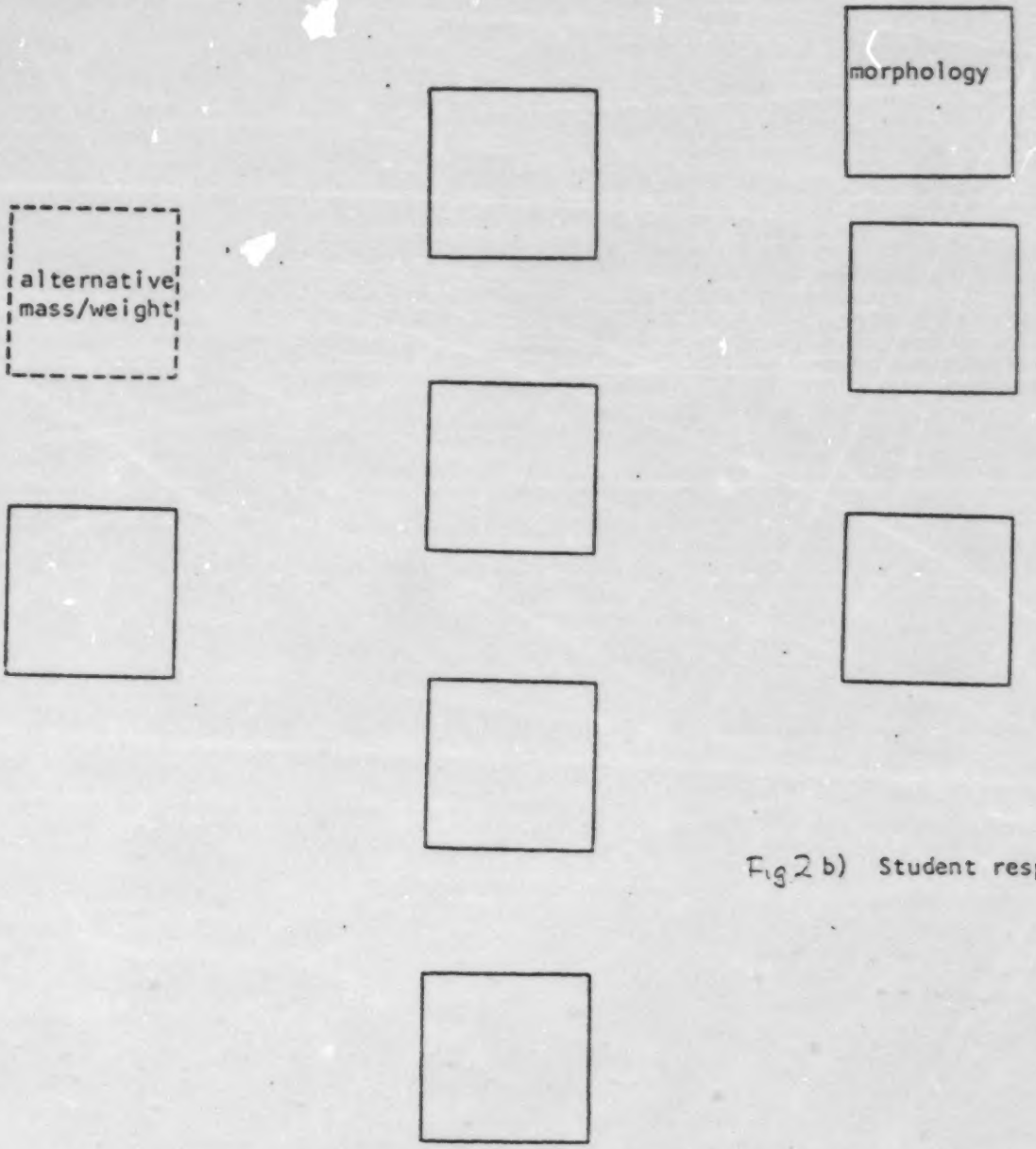


Fig 2 b) Student response MAK 38

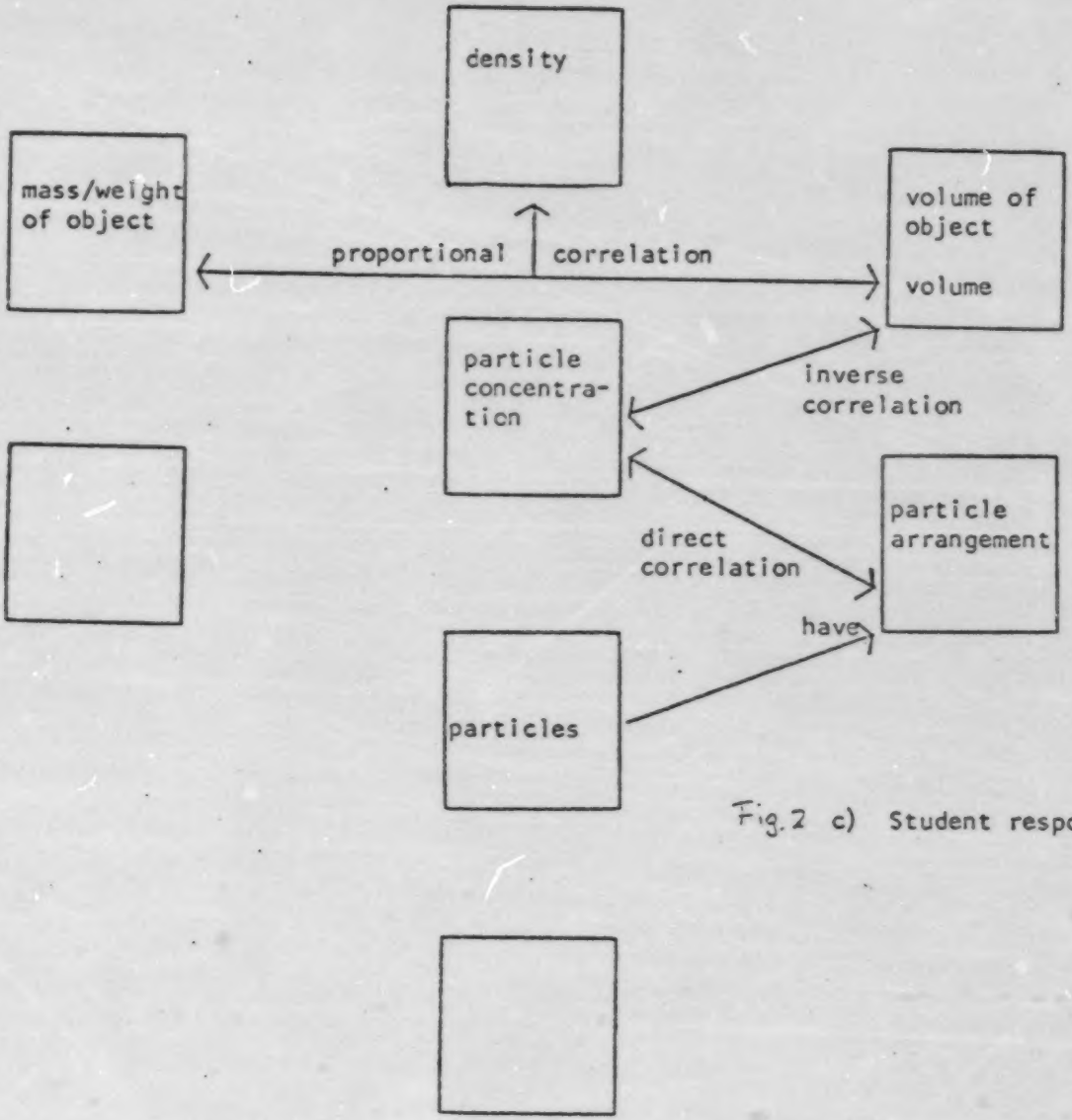


Fig.2 c) Student response SEL 54

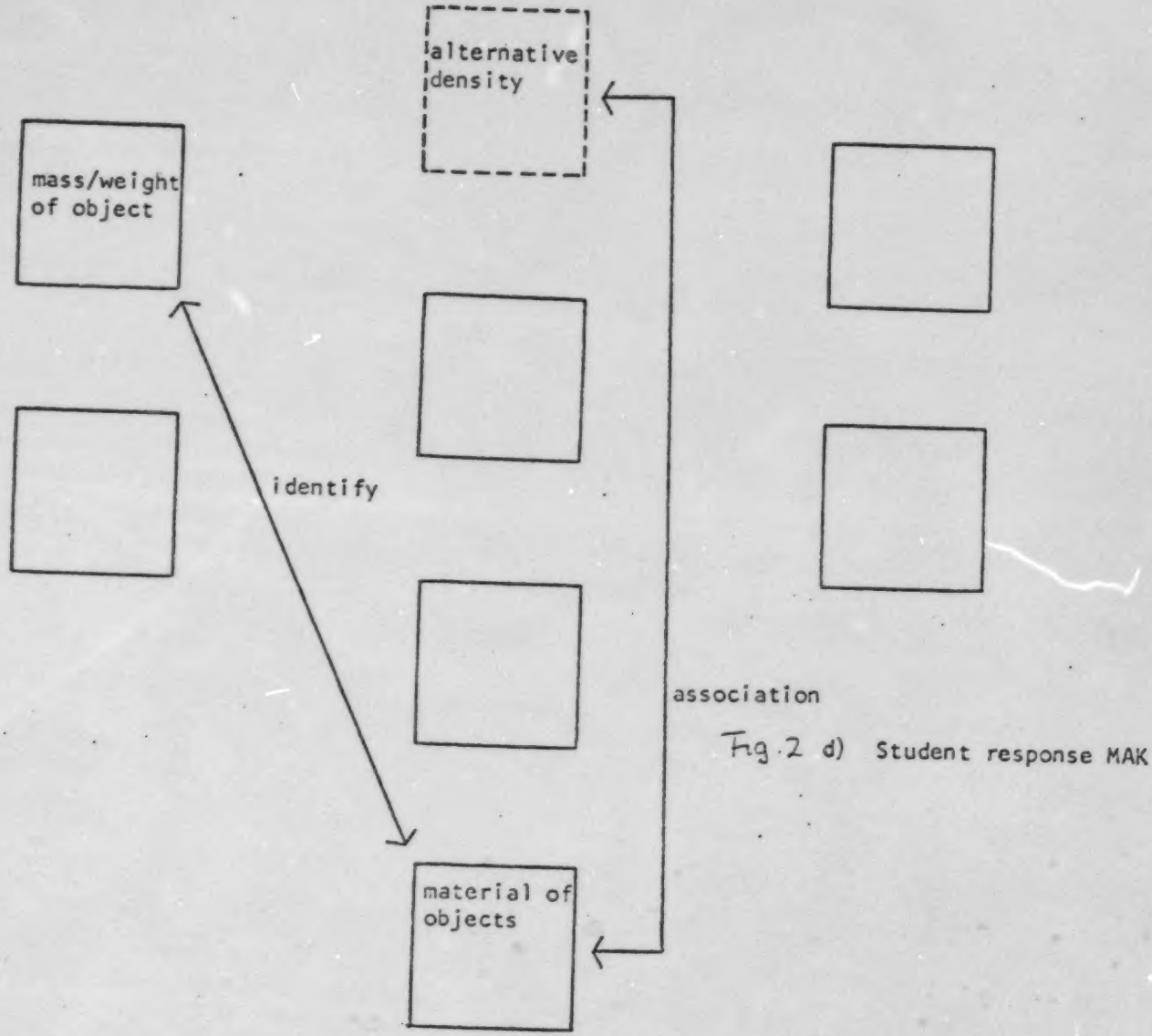


Fig. 2 d) Student response MAK 104

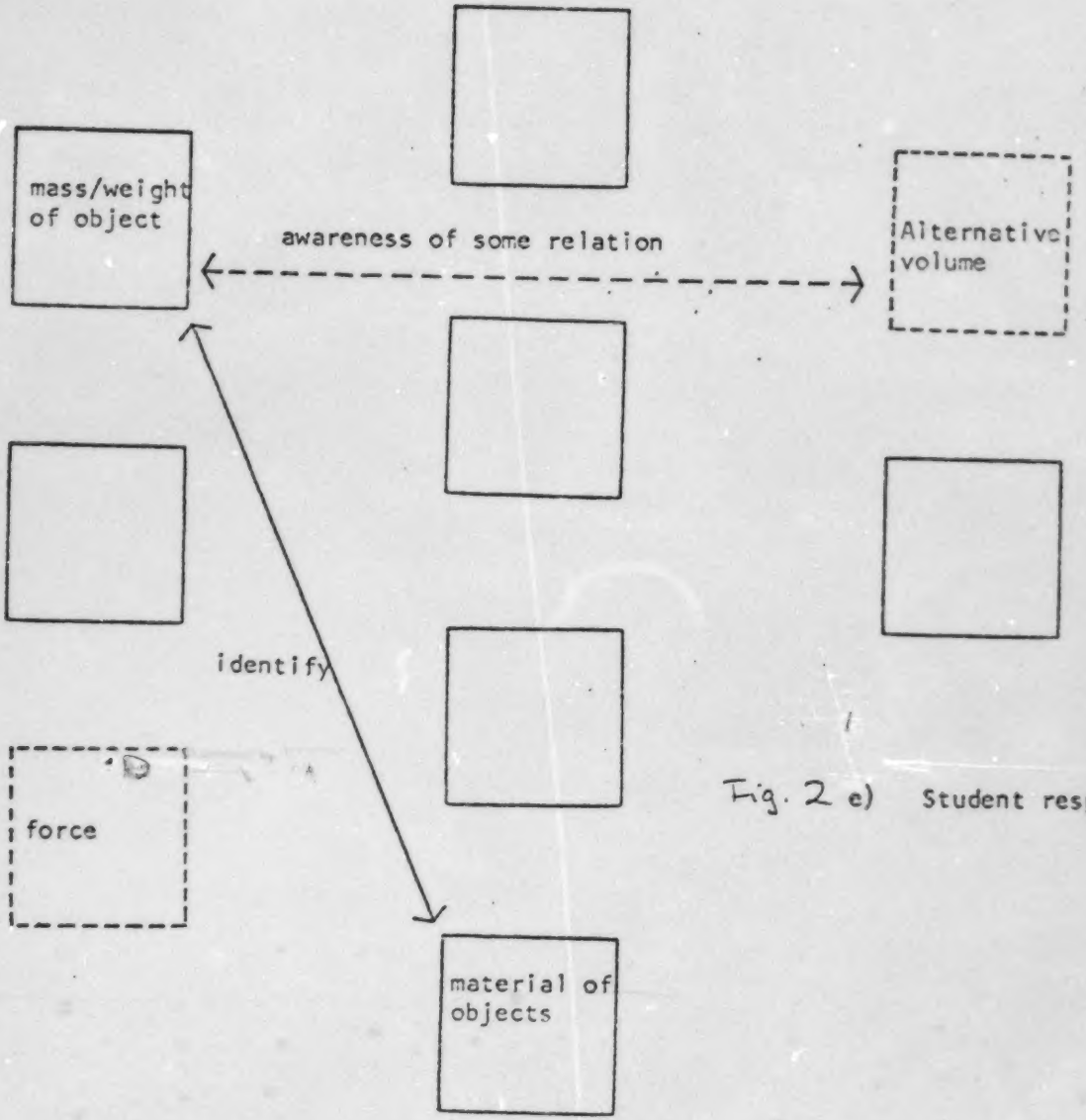


Fig. 2 e) Student response MAN 73

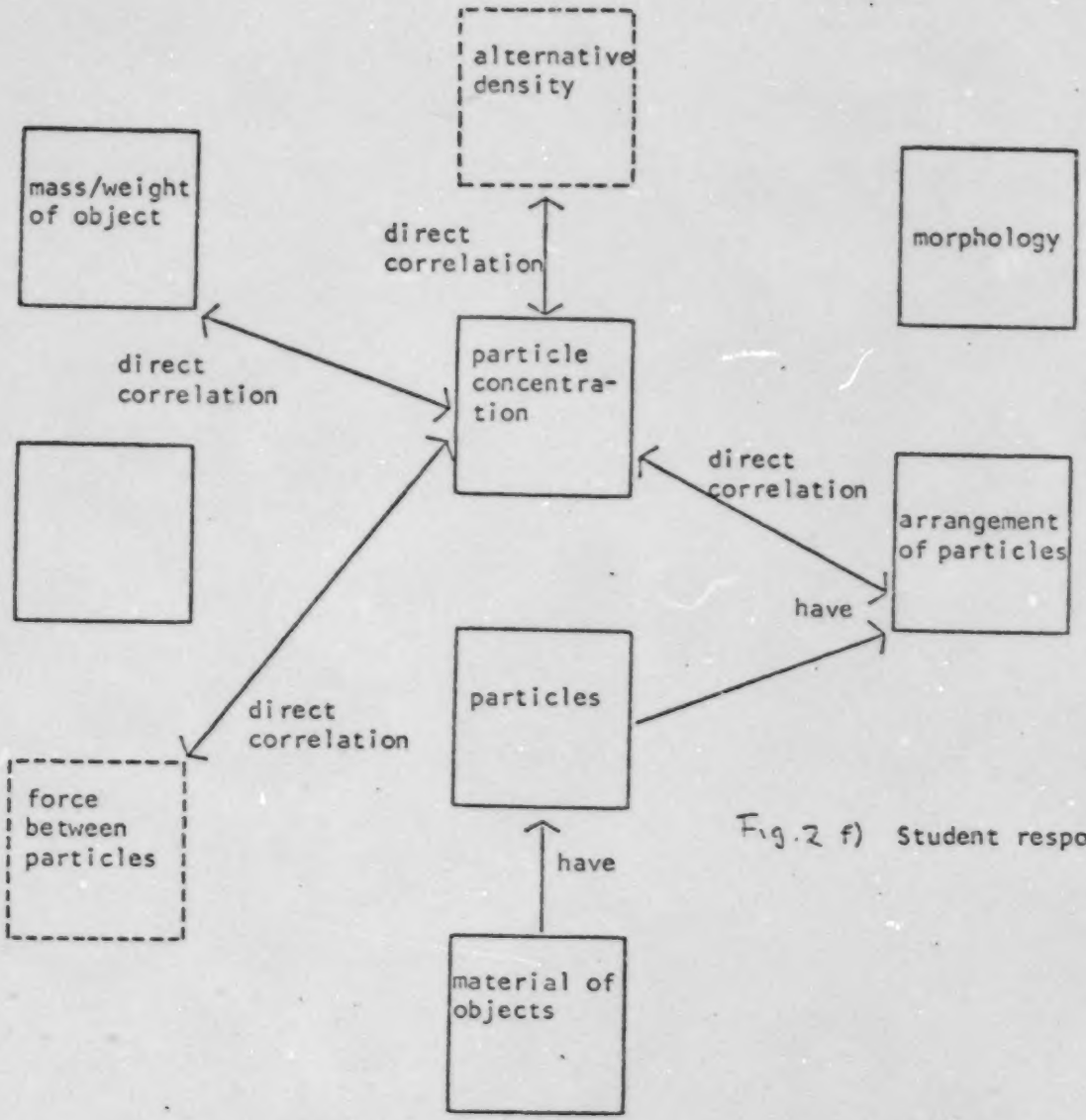


Fig. 2 f) Student response MAM 135

TABLE I

Transcript	Interpretation	Classification
I - (Introduces task).		
S - This (lid) will not sink if I put it in this way (flat) but will sink if I put it in this way (end on).		
(Sorts objects into two piles).		
I - What is your reason?		Scientific conception of mass/weight
S - These which are sinking have more mass and they have no big spaces between the molecules. They are not so much hard as those that are not sinking. Those that are sinking are hard.	S explains that sinking objects have more mass. This is caused by the way the molecules are packed, i.e. the molecules have have less spaces between them, inferring they are closely packed. S links this idea with the property of hardness. There is a logical connection in these ideas which form a set of integrated conceptions.	Alternative conception of density
I - Hard? (I. probes for further information).		
S - Yes.	MASS IS IMPORTANT PACKING OF PARTICLES IS IMPORTANT	
I - Alright, let's check now.		
S - (Experiments with various objects including flat yellow plastic lid).		
I - Why does this plastic lid float but that white plastic hook sinks?	S now resorts to a morphological explanation involving the sharpness of object due to the shape.	Scientific conception of morphology
S - This one is too flat - it has not got sharp points like this (hook). When I put (the hook) in water, it goes straight down. When I put this one (lid) it has the flat surface which keeps it on the water - that's why when I put it (flat) it remains on the top but when I put it (end on) it goes down.	SHAPE OF OBJECT IS IMPORTANT.	
I - So the shape is important? (I. reiterates question to ensure S. is convinced).		
S - Yes, the shape.		
I - This yellow flat lid?	S introduces idea of conflicting forces, i.e. the water has energy to push an object upwards and weight of object has a downward effect (or force). This idea involves the integrating and generalisation of ideas concerning energy of objects which oppose each other and the mass of object is related in some way to energy. Student uses word energy, but the meaning could include force.	
S - It will not sink		
I - And if you push it?		
S - It comes up again.		
I - So, what's the difference? These are both flat, this black one (saucer) and this yellow one (lid)? (I. produces a conflict situation).	THE ENERGY IN WATER COUNTERACTS THE WEIGHT OF OBJECT.	Alternative conception of force
S - They have not got equal masses. This one (black) has greater weight than this one (yellow), and now this water cannot hold it when I put it in;water has energy to take this on a level.	COMPARATIVE MASS OF OBJECTS.	Scientific conception of mass/weight

BEST COPY AVAILABLE

Topic: The floating and sinking of objects in water. Page a

Sample: Forty high school students from Qwa Qwa, South Africa. (The number of students identified as holding particular conceptions is given in parentheses. The exemplars are quoted from students identified by a code number).

1. Morphology (11)

   1.1 Sharp edges (9)

   "It sinks because its side is sharp to cut the water". (MAK 133).

   1.2 Shape (3)

   "This bead is sinking because it has a hole through it. This (pin) sinks, I think it is because of the knob". (MAN 25).

2. Alternative Force (17)

   2.1 Objects have force/power/strength/energy (5)

   "The stone, irons and brick, er, have power. Power means energy...The power of this thing is too light... something which doesn't have power is not heavy, is too light". (MAK 63).

   2.2 Water exerts a force on object (8)

   "Because of the force of the water it comes up". (MAK 180).

   2.3 Counteracting forces of object and water (9)

   "This (object) has got greater weight than this (object) and now this water cannot hold it (object 1). Water has energy to take this (object 2) on the level". (MAK 124).

3. Mass/Weight

   3.1 Scientific mass/weight (32)

      3.1.1 Comparative mass/weight of objects (32)

      "This (object) has light weight. This (object) has heavy weight". (MAM 57).

      3.1.2 Comparative mass/weight of object and water (3)

      "This one (floats) because it has less, er, weight than the water, so the object will have to go upwards". (MAN 2).

      3.1.3 Comparative mass/weight of particles (3)

      "It will float because its particles are lighter than the particles of water". (MAK 82).

   3.2 Alternative mass/weight (16)

      3.2.1 Mass/weight is a property of some objects (6)

      "Always the corky things and those that are made out of plastic are floating... They haven't got weight... they cannot sink". (SEL 100).

      3.2.2 Mass/weight is relative, not absolute (2)

      "(The object) has a different weight according to how you put it (in the water). When you put it (edge on) it has more weight". (MAK 180).

      3.2.3 Mass/weight closer to meaning of density (14)

      "When something is crushed its 'weight' is going to be less than it would be in a normal state". (MAK 11). "The lid is lighter than the pin". (referring to large plastic lid) (MAM 64).

4. Volume

   4.1 Scientific volume (1)

      4.1.1 Volume is the space occupied by objects (1)

      "Uh, how the particles are made close together, this one's volume is greater than this one's". (SEL 54).

   4.2 Alternative volume (8)

      4.2.1 Intuitive idea of size or quantity (8)

      "It is floating because in this container it (plastic lid) occupies more 'distance' than the other one (tin lid) which I put in the water". (MAM 63).

5. Density

   5.1 Scientific density (5)

   "The densities of sinking objects are more than floating objects". To measure density "I'm going to divide the mass by the volume then I get density". (SEL 54).

   5.2 Alternative density (27)

      5.2.1 Intuitive ideas of solidness of material often based on a tautological definition (23)

      "The bead is heavier (than the yellow lid) because it has a solid, er ... uh, uh, this lid is heavier than this bead but in water it (the bead) is heavier".

      "But the material of this thing (pin). It all depends on the material". (SEL 70).

      5.2.2 Denseness of particles which involves the way the particles are packed (18)

      "Those which are sinking have more mass and they have no big spaces between the molecules". (MAK 124). "What causes it to sink is that it has a greater density than the density of water ... Maybe the particles of certain objects are too much bound or closed. If they are too much closed it is possible for the object to sink, and if its particles are not too much closed, er, it can float". (MAM 147).

BEST COPY AVAILABLE

TABLE III

Student	A.0 Morphology	B.0 Alternative Force	C.1 Mass/wt	C.2 Alternative Mass/wt	D.1 Volume	D.2 Alternative Volume	E.1 Density	E.2 Alternative Density
MAN 190		x					x	x
228							x	x
132		x	x					x
135	x	x	x					x
219		x	x				x	x
57		x	x					x
63			x			x		x
147		x	x			x		x
MAN 73			x	x		x		x
25	x							x
110			x					x
51								
2			x					
64	x	x	x	x				x
SEL 82		x	x					
109		x						x
100				x				x
106			x					x
54			x		x		x	
70			x	x				x
24		x	x	x				x
71			x			x	x	x
114			x					x
MAK 3		x	x	x				x
124	x	x	x	x				x
38	x		x	x		x		
180		x	x	x				x
104			x	x				x
26	x	x	x	x				x
183	x		x					
133	x		x			x		x
11	x	x	x	x		x		x
82			x					x
36	x		x	x				x
118		x	x	x				x
15			x	x				x
63		x		x				
77	x		x			x		x
76			x					
171	x		x	x				
Total	12/40 30,0%	17/40 42,5%	33/40 82,5%	17/40 42,5%	1/40 2,5%	8/40 20,0%	5/40 12,5%	31/40 77,5%

TABLE IV

SPI Exemplars	Relationship
A.1 "It sinks because its side is sharp to cut the water". MAK 133. "This bead is sinking because it has a hole throughout". MA 25. "The pin sinks. I think it is because of the knob". MAN 25.	Identification (of possible factors influencing sinking) = unrelated conceptions
B.1 "The stone, irons, and bricks er, have power. Power means energy... The power of the stone is too strong. The power of this thing is too light...Something which doesn't have power is not heavy, is too light" MAK 63.	Comparison (of power of object) = simple relations
B.2 "This object has got greater weight than this (object) and now this water cannot hold it. Water has energy to take this object on the level". MAK 124.	Correlation (of amount of power with amount of weight) = complex relations
C.1.1 "This object has light weight. This object has heavy weight" MAM 57	Comparison (weight of objects compared) = simple relations
C.1.2 "This one (floats) because it has less, er, weight than the water, so the object will have to go upwards". MAN 2.	Comparison (weight water compared with weight object) = simple relations
C.1.3 "It will float because its particles are lighter than the particles of water". MAK 82.	Comparison (weight of object particle with weight of water particles) = simple relations
C.2.1 "Always the corky things and those that are made out of plastic... They haven't got weight... they cannot sink". SEL 100.	Identification and comparison (of effect of particular materials associated with weight) = simple relations
C.2.2 "(The object) has a different weight according to how you put it (in the water). When you put it (edge on) it has more weight". MAK 189.	Comparison (inserted position changes the 'weight') = simple relations
C.2.3 "When something is crushed its 'weight' is going to be less than it would be in a normal state". MAK 11.	Correlation (amount of crushing correlates with 'weight') = complex relations
D.1 "Uh - how the particles are made close together, this one's volume is greater than this one's". SEL 54.	Correlations (packing of particles correlated with volume) = complex relations
D.2 "It is floating because in this container it (plastic lid) occupies more distance than the other one (tin lid) which I put in the water".	Comparison ('volume' compared to explain floating) = simple relations
E.1 "The densities (of sinking objects) are more than this (floating object). To measure density I am going to divide the mass by the volume, then I get the density". SEL 54.	Proportions (mass and volume in proportional relationship) = complex relations
E.2.1 "The bead is'heavier' than the yellow lid) because it is solider -- This lid is heavier than this bead but in water it (the bead) is heavier". MAK 104.	Comparisons (solidness compared to explain floating and sinking) = simple relations
E.2.2 "The water particles are more heavy than the wood particles, they are more closely packed than the wood particles". MAM 63.	Correlations (packing of particles correlated with weight) = complex relations
"Maybe the particles of certain objects are too much bound or closed. If they are too much closed it is possible for the object to sink. If its particles are not too much closed er, it can float". MAM 147.	

The reliability of these findings was checked by asking an independent assessor to analyse the exemplars for the type of relationship involved. Eighty-six per cent agreement was obtained.

BEST COPY AVAILABLE